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EFFECTS OF VARIOUS CONCENTRATIONS OF DDT ON SEVERAL SPECIES OF FISH OF DIFFERENT SIZES

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EFFECTS OF VARIOUS CONCENTRATIONS OF DDT ON SEVERAL SPECIES OF FISH OF DIFFERENT SIZES

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Introduction

Field Studies began in 1945 indicate that there is a difference in the susceptibility of fishes of different ages to DDT, as well as interspecific differences. Hoffmann and Surber (1948) observed that young of-the-year of smallmouth black bass (Micropterus dolomieu), common suckers (Catostomus commersonnii), and stoneroller suckers (Hypentelium nigricans) were killed by a one-pound-per-acre aerial application of a DDT suspension in a section of Back Creek, W. Va. The adults of these species were not affected. Pielou (1946) found young Kafu bream (Tilapia kafuensis) sensitive to DDT in paraffin solution when the concentration of DDT reached one part in 25 million parts of water in dirt-bottomed ponds. Fish were more sensitive to DDT in the aquarium experiments.

As a result of the field observations, it seemed advisable to conduct experiments to determine differences in the toxicity of DDT in relation to size and species of fish.

The experiments were carried out at the U. S. Fish and Wildlife Service Experimental Station, Leetown, W. Va., with a variety of warm and cold-water fishes. Various sizes of fish were exposed to different formulations and concentrations of DDT so that differences between age-group and species susceptibility could be determined.

Methods

The experiments were conducted in several types of ponds. A number of experiments were performed in a series of dirt-bottomed ponds (fig. 1), while others were carried out in concrete pools and raceways.

Spraying was done with a continuous-spray hand atomizer or a knapsack sprayer. The spray was applied to the larger ponds from a canoe controlled by two men on the banks to insure a thorough coverage. It was necessary to use the same ponds several times during the season, hence, a biological assay of each pond for DDT was made before its reuse, by exposing larvae of Aedes egypti(Linnaeus), a species of mosquito killed by 0.005 p.p.m. of DDT.

Note; The writers are indebted to Edward P. Merkel and John Trach, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, and to Dorothy D. Friddle, Branch of Fishery Biology, U. S. Fish and Wildlife Service, for technical assistance during the course of these studies.

A series of six concrete-bottomed daphnia ponds (fig. 2) measuring 25 by 8 by 3 feet (surface area 200 square feet, volume 450 cubic feet) were found to be ideal for many of the experiments, especially when replications were desired. Upon completion of an experiment, each pond was drained, the sides and bottom scraped, brushed, and thoroughly rinsed with fresh water before refilling.

Experiments were also conducted in glass aquaria of 5 to 10 gallons capacity. At the conclusion of an experiment, each aquarium was washed with a saturated salt solution, scrubbed with cleanser, and rinsed with acetone and water.

A few experiments were conducted in concrete raceways (fig. 3), each of which has an area of 0.023 acre, a volume of about 1,350 cubic feet of water and a continuous flow through the pond.

The following DDT formulations were used in the experiments:

Formula 1: 25 percent wettable powder (commercial product).

Formula 2: 50 percent wettable powder (commercial product).

Formula 3: 50 percent wettable powder (commercial product of another company).

Formula 4: 90 percent wettable powder formulated by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Formula 5: one pound DDT, 2 pints xylene, and fuel oil No. 2 to make one gallon.

Formula 6: one pound DDT, 3,180 milliliters of napthenic solvent (PD-544-B) and fuel oil to make one gallon.

Experiments with Young Fishes

Suspensions

Rainbow (*Salmo gairdnerii*), brook (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*), 1.5, 1.6 and 1.5 inches, respectively, were exposed to a concentration of 0.25 pound DDT in suspension per acre (0.15 p.p.m.). Seven aquaria, including one control, each containing 18 liters of water were stocked with three fish of each of the above species. The aquaria were filled and stocked March 8 and sprayed with wettable DDT (formula 2) by means of a hand atomizer on

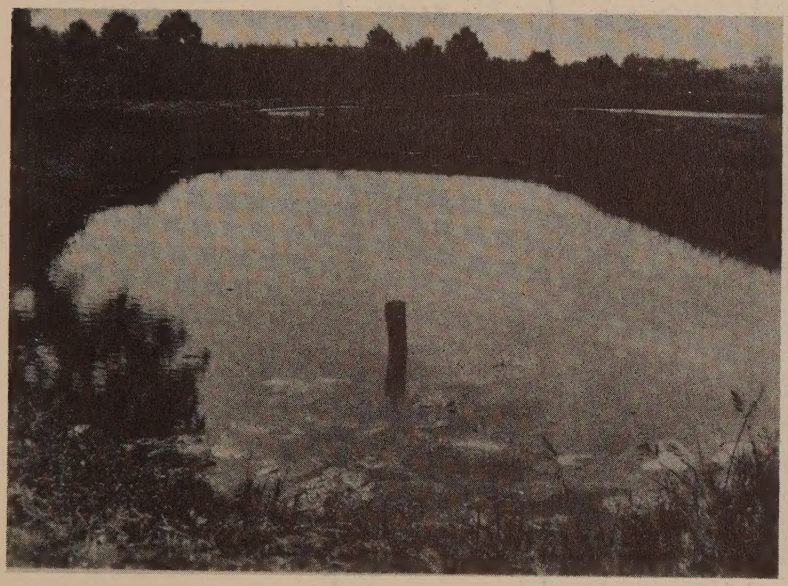

Figure 1.—One of a series of dirt-bottomed ponds used for DDT experiments.

Table 1.—Area and volume of ponds (I series)

Pond No.	Area acres	Volume, cubic feet	Concentration in p.p.m. of DDT at one pound per acre
1	0.43	44,954	0.15
2	0.042	3,794	0.18
3	0.053	5,100	0.16
4	0.051	4,664	0.17
5	0.062	5,417	0.18
6	0.120	8,939	0.21
7	0.108	11,949	0.14
8	0.35	40,402	0.14
9	0.107	9,788	0.17
10	0.088	10,848	0.13
11	0.097	14,365	0.11
12	0.051	8,886	0.09
13	0.056	9,268	0.10
14	0.068	11,848	0.09

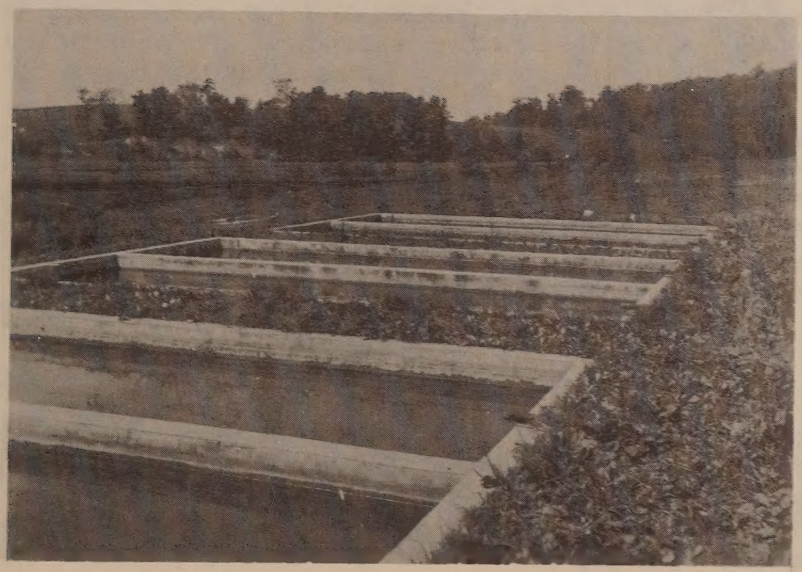

Figure 2.—Concrete daphnia ponds used in DDT experiments.

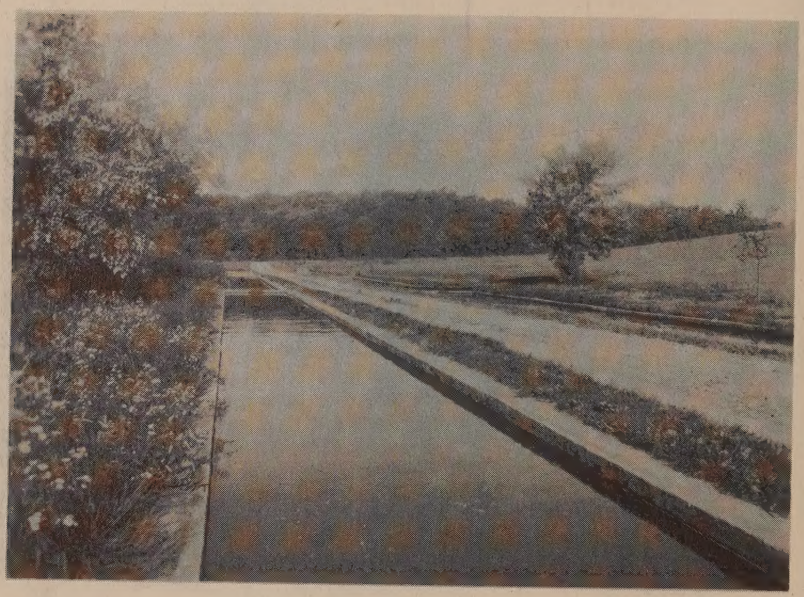

Figure 3.--The D series of trout raceways at Leetown.

March 18. The water temperature during the experimental period averaged 54.2° F. No fresh water was added to the aquaria after the initial filling. These DDT applications killed all but three fish in the sprayed aquaria, and one out of 9 fish died in the control.

Nine dirt-bottomed ponds were stocked with 200 each of the advanced fry of the smallmouth black bass (Micropterus dolomieu) and the largemouth black bass (Micropterus salmoides) on June 4, 1946. The average size of the smallmouth black bass was 0.93 inches and that of the largemouth black bass 0.97 inches. Three ponds were left untreated as controls while the remaining six were sprayed with two DDT formulations on June 6 (table 2). There was ample natural food for the fish as there had been no previous treatments in this series of ponds during the 1946 season, and they were not drained during the winter. The ponds were drained and inventoried June 18 and 19, 12 days after treatment.

Eighty-eight percent of the bass were recovered from the control ponds, but no fish survived in the other ponds, with one exception. In the pond treated with an oil spray about 12 percent of each species survived. In oil-sprayed ponds, the oil film is sometimes blown ashore by breezes. Removal of the film by a breeze or a lower concentration of DDT may have accounted for the fact that there was some survival in one pond.

Oil Formulations

Three daphnia ponds were stocked with 100 advanced fry of the largemouth black bass which averaged 1.1 inches in fork length on June 18, 1947. The fry were supplied an abundance of Daphnia magna for food one day before ponds 1 and 2 were sprayed with oil formula 6 at the rate of 0.5 pound DDT per acre (0.09 p.p.m.) on June 19. Pond 3 remained untreated. The average temperature during the experiment was 72.0° F. About 85 percent of the fish present in the two treated ponds were dead by the end of the second day, and no live fish were recovered upon draining the ponds June 24. All fish were recovered in the control pond. In the treated ponds, Daphnia magna disappeared four days after treatment, although they were abundant in the control pond at the conclusion of the experiment.

These ponds were restocked with the same numbers of slightly larger fish (average length, 1.25 inches) on June 29, 1947. A 0.25 pound per acre treatment (0.04 p.p.m.) on June 30 with oil spray (formula 6) killed all the fish in the two experimental ponds, while 97 percent of the fish survived in the control pond until July 7, when the experiment was terminated. The heaviest mortality occurred on the second day after treatment. The average temperature during this experiment was 75.0° F.

Table 2.—Effects of DDT on the advanced fry of largemouth and smallmouth black bass.1/

Pond No.	Spray formula	DDT per acre pounds	DDT parts per million	Percentage of survival	
				Smallmouth black bass	Largemouth black bass
2	Control	0.0	0.0	93.0	89.0
3	Control	0.0	0.0	87.0	95.0
6	Control	0.0	0.0	89.5	81.5
10	Wettable DDT (formula 1)	0.50	0.065	0.0	0.0
11	Wettable DDT (formula 1)	0.37	0.041	0.0	0.0
13	Wettable DDT (formula 1)	1.00	0.100	0.0	0.0
4	DDT in oil(formula 5)	0.50	0.085	0.0	0.0
5	DDT in oil(formula 5)	0.50	0.090	0.0	0.0
7	DDT in oil(formula 5)	0.50	0.070	13.0	11.5

1/ The average temperature in pond No. 7 (I-series), a representative pond, from June 6 to June 18, based on records for 6:00 a.m., noon, 6:00 p.m., and midnight, was 75.7° F.

Three daphnia ponds were each stocked with 50 bluegills (Lepomis macrochirus) averaging 1.0 inches in length on August 5, 1947. Two of these ponds were sprayed on August 6, with oil spray (formula 6) at the rate of 0.25 pound per acre (0.04 p.p.m.); the third pond remained untreated. The average temperature during the experimental period, August 6 to 10 was 72.9° F. The heaviest mortality (about 70 percent) occurred three days after treatment. When the ponds were drained on August 10, 80 percent of the fish were dead in one sprayed pond and 90 percent in the other, but no fish died in the control pond.

Several dirt-bottomed ponds contained adults and recently hatched fry of the golden shiner (Notemigonus crysoleucas). These young fish ranged from 0.3 to 1.1 inches in length. Since fry of this size cannot be handled readily, a count was made of the schools of young fry about the borders of four ponds to note their presence and relative abundance before spraying.

On June 20, 1947, pond 10 was sprayed with DDT in oil (formula 6) at 0.5 pound per acre (0.065 p.p.m.). Affected fry were found about the entire shore line 24 hours later. Their nervous reactions often left them stranded more than an inch from the water's edge. As far as could be determined, all fry were killed, but the adults survived.

A second pond (13) containing golden-shiner fry was sprayed at the same time at the rate of 0.25 pound per acre (0.025 p.p.m.). No young fry could be found two days later.

A third pond (11) was sprayed with oil spray (formula 6) at 0.125 pound per acre (0.014 p.p.m.) on June 30, 1947. Fry were observed for nine days after treatment, and were apparently unaffected by the dosage. During this period the golden-shiner fry in control pond 7 remained in evidence. The average temperature for these ponds during this period was 72.0° F.

Suspensions and Oil Formulations

Nine dirt-bottomed ponds were stocked with 600 fish—200 each of fingerling bluegills, brown bullheads (Ameiurus nebulosus), and black crappies (Pomoxis nigro-maculatus) hatched during the 1946 season. The young bluegills had an average weight of 0.56 pound per thousand (1.0 inch in length), black crappies 0.34 gram each (1.2 inches), and brown bullheads 0.17 gram each (length not recorded). Six ponds were sprayed July 11 and all were drained on July 19.

Table 3.--Effects of DDT suspension and oil solution sprays on young warm-water fishes

(Average water temperature for period, July 11-17, 1946, was 78.9° F.)

Pond No.	Spray formula	DDT per acre pounds	DDT parts per million	Percentage of survival		
				Bluegill	Black crappie	Brown bullhead
2	Control	—	—	89.0	82.0	91.0
3	Control	—	—	82.0	98.0	95.0
1/ 6	Control	—	—	79.5	92.5	89.0
4	Wettable DDT (formula 2)	0.50	0.085	34.0	22.5	51.0
5	Wettable DDT (formula 2)	0.50	0.090	29.5	34.5	92.5
7	Wettable DDT (formula 2)	0.50	0.070	84.0	85.5	89.5
2/ 10	DDT in oil (formula 5)	0.50	0.065	23.5	7.5	12.5
3/ 11	DDT in oil (formula 5)	0.37	0.040	13.0	31.0	39.0
13	DDT in oil (formula 5)	1.00	0.100	30.0	23.0	19.5

1/ Contained one largemouth black bass - length, 4 inches.

2/ Contained 18 green sunfish (entered through water supply line or drain).

3/ Contained 9 green sunfish (entered through water supply line or drain).

Suspension Formula (formula 2) wettable powder) at 0.5 pound per acre caused serious losses in all three ponds. These losses were less than in the ponds treated with an oil formula (formula 5). The brown bullhead may be less sensitive to DDT in suspension than the bluegill. The results were variable, but considerable numbers of fish survived as shown in table 3.

Eight aquaria filled with 20 liters of water were stocked on January 24, 1947, with four bluegills, four rainbow trout and four brook trout each. These species were of the following sizes, respectively: 1.1 inches, 1.0 inches, and 0.9 inches. The water temperature averaged 61.8° F. On January 28, 1947, three aquaria were sprayed with DDT suspension (formula 2) at the rate of 0.5 pound per acre (0.28 p.p.m.), and three aquaria were sprayed with DDT in oil (formula 5) at 0.5 pound DDT per acre (0.28 p.p.m.). Two similarly stocked aquaria remained untreated. All fish died in the sprayed aquaria; the heaviest mortality occurring on the second and third days after spraying. The experiment was concluded on February 2.

Experiments with Older Fishes

Three examples of the ability of large fingerling and adult fish to withstand high concentrations of DDT were cited by Surber (1946). In one instance, two small dirt-bottomed ponds which were stocked with 50 smallmouth bass (average length 3.7 inches), and 50 bluegills (average length about 3.8 inches), were sprayed on September 8, 1945, with a DDT oil solution (formula 5) at the rate of one pound of DDT per acre, 0.14 and 0.13 p.p.m., respectively. Losses totaled 46 and 54 percent, respectively, of the smallmouth bass; 24 and 8 percent of the bluegills.

In a second instance, a 0.35 acre dirt-bottomed pond containing 20 adult largemouth black bass, 10 to 15 inches, and 40 adult bluegills, 6 to 7 inches, was sprayed with DDT in kerosene at the rate of one pound per acre (0.14 p.p.m.) on September 13, 1945, and again on September 20, without loss of a fish.

In the third experiment, October 24, 1945, three dirt-bottomed ponds containing 50 bluegills 3.6 inches in length, and 50 largemouth black bass averaging 4.9 inches, were sprayed with DDT and xylene in fuel oil No. 2 (formula 5) at one pound of DDT per acre. Fifty to 60 percent of the bluegills were killed, but the treatment had little effect on the fingerling bass. The maximum theoretical concentrations of DDT in the series of experiments ranged from 0.14 to 0.17 p.p.m. The three ponds were restocked with the same species of fish of comparable size. A suspension of DDT used at the above rate did not kill the bass. One-half the bluegills were found dead in one of the three ponds, and one bluegill in another.

Table 4.—Effects of DDT suspension (formula 2) on trout and other fishes in raceways [1/]

Pond No.	Brook trout (Average length, 3.8 inches) Number stocked	Number recovered	Killed by DDT	Percentage of survival	Rainbow trout (Average length, 3.5 inches) Number stocked	Number recovered	Killed by DDT	Percentage of survival
1	100	87	0	87.0	100	87	0	87.0
2	100	74	0	74.0	100	89	0	89.0
3	100	97	1	97.0	100	95	1	95.0
4	100	79	1	79.0	100	88	0	88.0
	Smallmouth black bass (Average length, 3.2 inches)				Golden shiner (Average length, 4.1 inches)			
1	88	88	0	100.0	100	94	0	94.0
2	92	91	0	98.9	100	99	.0	99.0
3	92	87	1	94.6	104	85	10	81.7
4	62	59	0	95.2	100	99	1	99.0

1/ The average temperature during the period August 12 to 20 for pond 1 was 62.8° F.; for pond 2, 63.6° F.; for pond 3, 64.6° F.; and for pond 4, 65.5° F.

Suspensions

On August 10, 1946, four trout raceways (fig. 3), each with an area of 0.023 acre and a water fall of 8-12 inches between each raceway, were stocked with trout and other fish (table 4). The rate of flow in the uppermost raceway was 130 gallons per minute, whereas it was 80 gallons per minute in the third raceway as water was lost underground through a crack in the bottom of pond 2. Spraying was started at 7:20 p.m., on August 12, in the uppermost raceway, and completed in the last one 55 minutes later. The wettable DDT (formula 2) spray was applied with a hand atomizer at the rate of one pound of DDT per acre (maximum possible concentration in uppermost pond, 0.258 p.p.m.).

In pond 3, one smallmouth black bass and one rainbow trout were found dead in the morning after the spray application and may have been killed by DDT. Early in the afternoon one dead golden shiner was collected from this pond, and others were observed to be sick. The affected fish did not school with the other fish and swam in circles in an erratic manner. Seven of 10 golden shiners killed by DDT in pond 3 died within 24 hours after the spray application. For some inexplicable reason, 13 of the 15 fish killed by DDT were found in pond 3. Pond 4 probably received the most DDT, for, in addition to being sprayed, it received the run-off from the other three ponds.

The experiment indicates that a DDT suspension, applied at the rate of one pound of DDT per acre to a flowing stream, could cause negligible losses to brook and rainbow trout, smallmouth black bass, and golden shiners under conditions similar to those of this experiment.

On August 23, 1946, each of six daphnia ponds (fig. 2) were stocked with 200 fish (50 each of smallmouth black bass, largemouth black bass, bluegills,, and golden shiners). Ponds 3 and 4 were treated with suspension formula 3, ponds 5 and 6 with suspension formula 2, containing DDT at one pound per acre (0.18 p.p.m.). Ponds 1 and 2 served as controls. The applications were made with a hand sprayer on August 26. The ponds were drained September 9. The 50 percent wettable DDT powders of two manufacturers showed marked differences in toxicity (table 5). Possibly this was due to the nature of the wetting agents. The survival figures for the bluegills were all low due to predation on the part of the bass. Excluding fungus-killed fish and those taken by predation, figures are given in the table for those fish killed by DDT. Suspension formula 2 caused minor losses, whereas the suspension formula 3 accounted for sizable losses of all species. Greatest mortality occurred from three to seven days after treatment. This delayed action in toxicity was also noted when Back Creek was treated during midsummer of 1946 (Hoffmann and Surber 1948). However, in oil spray experiments in

Table 5.—Effects of DDT suspensions on fishes in daphnia ponds treated at the rate of one pound of DDT per acre [1/]

Pond No.	Spray formula	Smallmouth black bass, Average length, 3.2 inches: Number recovered	Killed by DDT	Percentage of survival	Largemouth black bass, Average length, 2.6 inches: Number recovered	Killed by DDT	Percentage of survival
[2/] 1	Control	50	—	100	48	—	96
2	Control	50	—	100	41	—	82
3	3	23	13	46	11	24	22
4	3	43	2	86	[3/] 20	15	40
5	2	49	1	98	41	2	82
6	2	49	1	98	36	1	72
		Bluegill, Average length, 2.0 inches			Golden shiners, Average length, 3.3 inches		
[2/] 1	Control	39	—	78	41	—	82
2	Control	28	—	56	37	—	74
3	3	15	10	30	9	15	18
4	3	12	5	24	24	10	48
5	2	16	4	32	48	1	96
6	2	21	1	42	49	—	98

1/ The average temperature of the ponds from August 27 to September 7 inclusive, was 71.2° F.

2/ Water snake captured in pond No. 1.

3/ One predator, largemouth black bass, in this pond.

Ash Creek, the Patuxent River, and Back Creek, 1947 (Surber and Friddle 1949), mortality of fishes reached a peak within two days after spraying.

Each of the daphnia ponds were again stocked on October 14, 1946 with 300 fish (50 each of black crappies, bluegills, largemouth and smallmouth black bass, rainbow trout, and golden shiners.

Ponds 1 and 2 were used as controls. Ponds 3 and 4 were sprayed with DDT suspension formula 3, and ponds 5 and 6 with suspension formula 2, both at the rate of one pound of DDT per acre (0.18 p.p.m.). All fish were fed a regular hatchery trout diet once each day. The average water temperature from October 22 through November 6 was 60.3° F. No running water was permitted to flow into the ponds during this experiment. Despite the fact that the water temperature reached 69.0° F., no loss of trout occurred in the control ponds.

Inasmuch as the condition of the fish has proved to be an important factor in their ability to withstand DDT, it is pointed out that the rainbow trout, golden shiners, largemouth black bass, and bluegills were recently removed from ponds in which they were well fed. The smallmouth black bass and black crappies, however, had been in holding ponds at least a week.

Both suspensions seriously affected black crappie, smallmouth black bass and bluegills (table 6). Nearly all of these species were killed by the one-pound-per-acre treatments. The golden shiners, rainbow trout, and largemouth black bass were relatively unaffected.

Although the primary objective of the experiment was to compare sensitivity of trout, a cold-water species, with that of warm-water species of fish under similar conditions in which it was known the fish would get full exposure to the poison, these data also furnish evidence that the larger fingerling fish can withstand more DDT than fry or fish about one inch long (see table 2 and page 11). The results of the experiment also show that well-fed rainbow trout and golden shiners can withstand a one-pound-per-acre treatment with DDT in suspension. The smallmouth black bass proved to be more susceptible to DDT than the largemouth black bass. This may have been due to the condition of the fish because in a previous experiment, largemouth black bass appeared somewhat more sensitive than the smallmouth black bass (table 5). The crappies died in large numbers immediately after spraying. Heavy losses in smallmouth black bass and bluegills occurred two to four days after treatment.

On August 23, 1946 nine dirt-bottomed ponds were each stocked with 350 fish--50 each of golden shiners (4.1 inches in length), and

Table 6.—Relative susceptibility of trout and warm-water fishes to DDT suspensions at one pound per acre (0.18 p.p.m.)

Pond No.	Spray formula	Smallmouth black bass, Average length, 3.1 inches: Number recovered	Killed by DDT	Percentage of survival	Largemouth black bass, Average length, 2.8 inches: Number recovered	Killed by DDT	Percentage of survival
1	Control	47	0	94	50	0	100
2	Control	48	0	96	50	0	100
3	Formula 3	15	35	30	50	0	100
4	" 3	13	37	26	49	1	98
5	" 2	11	39	22	47	3	94
6	" 2	11	39	22	44	6	88
		Bluegills, Average length, 2.1 inches			Golden shiner, Average length, 3.1 inches		
1	Control	50	0	100	50	0	100
2	Control	49	0	98	50	0	100
3	Formula 3	9	40	18	49	0	98
4	" 3	12	34	24	48	1	96
5	" 2	2	48	4	50	0	100
6	" 2	7	43	14	50	0	100
		Rainbow trout, Average length, 4.1 inches			Black crappie, Average length, 2.0 inches		
1	Control	50	0	100	45	0	90
2	Control	50	0	100	42	0	84
3	Formula 3	46	4	92	8	36	16
4	" 3	49	1	98	0	48	0
5	" 2	41	9	82	1	48	2
6	" 2	47	3	94	2	48	4

Table 7.—Effects of DDT suspensions on warm-water fishes.

(Average temperature of ponds from August 22 to September 2 was 79.5° F.)

Pond No.	Suspension spray formula	DDT parts per million	Percentage of survival				
			Smallmouth black bass	Largemouth black bass	Bluegill	Golden shiner	All species
I-2	Control	—	90	80	100	88	—
I-3	Control	—	86	99	100	92	—
I-6	Control	—	80	81	100	80	—
Average	—	—	85.3	86.7	100	86.7	89.7
1/ I-4	3	0.17	49	48	20	64	—
I-7	3	0.14	88	86	98	92	—
I-14	3	0.09	94	95	98	50	—
Average	—	—	77	76.3	72	68.7	73.5
I-10	4	0.13	65	61	66	88	—
I-11	4	0.11	71	64	86	72	—
I-13	4	0.10	100	82	100	88	—
Average	—	—	78.7	69	84	82.7	78.6

1/ Great blue heron, destroyed at this pond, probably responsible for low survival.

100 each of smallmouth black bass (3.1 inches), largemouth black bass (2.6 inches), and bluegills (2.4 inches). On August 26, three of these ponds were sprayed with suspension formula 3; and a second group of them with suspension formula 4, both at the rate of one pound of DDT per acre; while a third group of them served as a control. Fish survived well in both treatments except in one pond (I-4) which had been visited periodically by a heron (table 7). Formula 4 was apparently somewhat less toxic than suspension formula 3. An inventory of the ponds on September 4 showed that the survival rate was generally lower in the sprayed ponds than in the controls, indicating some effect from DDT.

Summary and Conclusions

A series of experiments with DDT formulations used in field applications for forest insect control were performed in dirt-bottomed ponds, concrete raceways, concrete daphnia ponds and aquaria at the Fisheries Experimental Station, Leetown, West Virginia, to test the toxicity of DDT to different species and sizes of fish.

Small bluegills, largemouth black bass, and smallmouth black bass one inch in length were killed by DDT in both suspensions and oil formulations in applications ranging from 0.25 to 1.0 pound per acre. Golden-shiner fry were killed by oil sprays in excess of 0.25 pound per acre in dirt-bottomed ponds.

Young black crappies 1.2 inches in length were killed by 0.5 pound per acre of DDT in both suspension and oil formulations.

Fingerling fish 2 inches or more in length were better able to withstand the higher rates of application. In some instances large fingerling or adult fish were able to withstand spray applications of as much as 1.0 pound of DDT per acre in both suspensions and oil formulations.

Fingerling bluegills, smallmouth black bass, and black crappies were found more sensitive to DDT than largemouth black bass, golden shiners, and trout.

In raceways with a continuous flow, brook and rainbow trout, smallmouth bass, and golden shiners were relatively unaffected by a 1-pound per acre application of DDT in a suspension formula.

In general, mortality with DDT suspensions occurred later and to a lesser extent than with oil sprays. Two commercial brands of wettable DDT, advertised as the same strength, showed a difference in toxicity.

LITERATURE CITED

Hoffmann, Clarence H. and Eugene W. Surber.
1948. Effects of an aerial application of wettable DDT on fish and fish-food organisms in Back Creek, West Virginia. Trans. Amer. Fish. Soc., Vol. 75 (1945), pp. 48-58.

Pielou, D. P.
1946. Lethal effects of DDT on young fish. Nature, Vol. 158, No. 4011, p. 378, September 14.

Surber, Eugene W.
1946. Effects of DDT on fish. Jour. Wildlife Management, Vol. 10, No. 3, July.

Surber, Eugene W. and Dorothy D. Friddle.
1949. Relative toxicity of suspension and oil formulations of DDT on native fishes in Back Creek, West Virginia. Trans. Amer. Fish. Soc., Vol. 76 (1946).

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